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Flower characters and self-fertilization capacity in relation to the bee pollination at sour cherry cultivars

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Summary: Detailed studies and comparisons were carried out on those flower characters of sour cherry cultivars that may affect bee pollination of flowers. Flower characters of sour cherry are fairly similar to other temperate zone fruit tree species. Their relatively small flowers distinguish the Cigánymeggy-types of cultivars from the flowers of tart cherries cultivars that are conspicuously larger, almost as large as the sweet cherry flowers. The relative position of flower organs was much more variable according to the season than according to the cultivars. So the differences were rather the consequences of seasonal effects than of variety features of sour cherry cultivars. As far as individual cultivars are concerned differences in the nectar production and the sugar concentration are revealed rather between groups of cultivars than between individual cultivars. The pollen production of flowers was extremely changeable in consecutive years. Most honeybees collected nectar at sour cherry flowers; pure pollen gatherers and mixed behaviour bees were half as frequent but differences among the behaviour of honeybees according to cultivars cannot be stated. The fidelity of honeybees to sour cherry is less expressed than to some other fruit tree species. Accordingly, it is very strongly suggested to take the competitive effect other plant species (weeds) flowering in and around the orchard carefully into account when organizing additional bee pollination in sour cherry plantations. Several sour cherry cultivars possess more or less self-fertilization capacity but this is greatly changeable according to the season. It has been proved that self-sterile sour cherry cultivars are sensitive even on the partial restriction of the effective time of bee pollination and it is to be stressed too that even in the case of partly self-fruitiful cultivars bee pollination is also vital in yield formation because medium or strong restriction of the effective bee pollination period is of a definite negative effect on their fruit set and yield. In years with unfavourable weather, the yield can dramatically be reduced sometimes down to nil. However, very high fruit set is also unfavourable because a negative correlation was detected between the final set and the mean mass of fruits.

Key words: sour cherry, cultivars, flower size, position of pistils, position of stamina, pollen production, nectar production, sugar concentration, sugar content of nectar, honeybees, foraging activity, gathering behaviour, nectar gatherers, pollen gatherers, mixed behaviour bees, flower constancy, pollen loads, restricted bee pollination, self-fruitiful cultivars, self sterile cultivars, competing flower species, self fertilization capacity

Introduction

The necessity of insect pollination in the commercial production of temperate zone fruits is beyond doubt (*Free*, 1970; *Benedek* et al., 1974; *McGregor*, 1976; *Tasei*, 1984; *Free*, 1993; *Benedek*, 1996). Up to now, research was concentrated to the comparison of pollination requirements of fruit species. Although some differences between cultivars within the same species were registered since long (*Free*, 1970, 1993; *Benedek*, 1996), little effort was spent to explore those differences in detail (e.g. *Soltész*, et al., 1983). During the last twenty years, however, cultivars of several entomophilous fruit tree species were studied intensely, as for their cultivar properties, which are influencing the efficiency of insect pollination (*Benedek*, 1996, 2003). We cannot state that even all the important commercial cultivars are thoroughly known. Experiences prove that information related to cultivar properties influencing the efficacy of insect pollination is particularly vital in the case of so called "intense" and "super-intense", high-density fruit plantations compared to the traditional orchards with large crowned trees.

In the case of sour cherries especially few detailed results can be found on this item in the world literature; and very few if any study was made to compare cultivars at the same place in given periods worldwide (see *Free*, 1993). Accordingly, in this paper we are summarising the published results (*Benedek*, et al., 1990, 1996; *Benedek & Nyéki* 1995, 1996; *Benedek & Nagy*, 1995; *Benedek*, et al., 2001; *Benedek*, et al., *2005*) and additional unpublished data of our studies having been made in this topic during the past 20 years.

Materials and method

Locality

Research work was carried out at four localities. Most studies were made at a collection of cultivars at Helvécia (NW of Kecskemét) and some additional observations were made in commercial sour cherry plantations at Kecskemét (South of Central Hungary) and Ujfehértó (NE Hungary) and the fidelity of honeybees as pollen gatherers to sour cherry flowers was also measured at a small sour cherry orchard at Pomáz (Central Hungary). Traditional large crown sour cherry trees were used for observations that were 10–15 years old ones at each site.

Flower size and the relative position of flower organs

We compared some morphological features of flowers at 11 sour cherry cultivars that may be important for bees when visiting them. We selected two trees being in flower simultaneously in a collection of cultivars and made measurements at 30 flowers per cultivar. The flowers inspected were taken randomly at the middle section of the crown that was convenient to sample. The diameter of flowers was measured (in mm), and the number of stamens per flower, the relative position of stamens to petals and finally the relative position of pistil to the stamens were evaluated (*Table* 1).

Nectar production of flowers

The nectar production (nectar content) of sour cherry flowers was measured with the classical capillary method at two trees per cultivars. Two flowering branches were selected for measurements at the Northern and the Southern side of selected each tree. The branches were covered with parchment paper bags on the day prior to the day of sampling. Nectar was taken with 3 capillary tubes per cultivars and 10 flowers were sampled per tube each occasion. Capillary tubes were stopped at both ends with two tiny beeswax balls weighted previously by a digital analytical scale at room temperature together with the pertaining tube. Tubes with nectar samples were weighted with the same digital analytical scale at room temperature. Measurements were taken at the morning (between 9:11:00) and in the afternoon (14:00-16:00) on days with weather favourable to the flight activity of bees. Sugar concentration of nectars (in per cent) was measured with an Abbe-type refractometer for each sample separately. Sugar production (sugar content) of flowers was calculated as a function of nectar production (nectar content) and sugar concentration. Results are shown in *Table* 2.

Pollen production of flowers

One hundred anthers from 10 flowers were taken randomly to determine the pollen production (pollen content) of anthers of some sour cherry cultivars. The anthers taken at a given cultivars were dissected together and the pollen was carefully washed out with distilled water. Finally the number of pollen grains was counted in Bürker-chambers under the microscope (*Table* 3).

Honeybee visitation of and gathering behaviour of honeybees at sour cherry flowers

One flowering branch was selected at the four directions of the compass at two trees per cultivars. There were 30 to 50 opening flowers at each branch. Honeybee visitation was observed for 10 minutes periods at each selected branch and also the foraging behaviour of flower visiting honeybees was registered. Four behaviour classes were searched for during field observations: (1) pollen gatherers, (2) nectar gatherers approaching the flower from the top, (3) mixed behaviour bees that gathered both for nectar and pollen, (4) side worker nectar gatherers. Results were expressed as honeybee visits per 100 flowers per 10 minutes periods of observation (*Tables* 4–5).

Fidelity of honeybees to sour cherry as pollen source

Pollen gathering honeybees were collected at flowering sour cherry trees in weather favourable to bee activity. Flowering plants were discovered in and around the plantation and their pollens were sampled and a small collection was prepared for comparison when identifying the pollen loads of honeybees taken at sour cherry flowers. Pollen loads were removed in the laboratory and their specific composition was identified under a microscope. Results are shown in *Table* 6.

Comparing self-fertilization capacity of cultivars to free pollination

20–30 cm long branches facing the four directions of the compass, 10 branches per cultivar, were covered by parchment paper bags at the white bud stage (that is prior to blooming has begun) to exclude pollinating insects and the bags were removed after petal fall. The number of flowers and 5 weeks later the number of fruits was counted. The number of fruits was related to the number of flowers and this value was treated as the final set. Another 10 branches per cultivar were selected and were left uncovered at the white bud stage to detect the effect of bee pollination at the open branches. The number of flowers was related to the number of fruits 5 weeks after the petal fall, similarly as at the branches covered to exclude pollinating bees (*Tables* 7).

Limiting the effective bee pollination period

The effective bee pollination period was limited at a self-unfruitful (*Pándy meggy*) and some completely self-fertile sour cherry cultivars (*Cigánymeggy, Újfehértói fürtös, Kántorjánosi, Debreceni bőtermő*). Four trees were selected of each tested cultivar and branches at the middle section of the crown were chosen for experimental purposes towards the four directions of the compass. Treatments were applied as follows: (1) = 0 % open (caged with parchment paper bags during the whole blooming period to exclude bees as pollinator), (2) = 35 % open early (free pollination during the first few days of the blooming, but caged afterwards from the 4th day of the flowering), (3) = 50 or 67 % open early (free pollination during the first half or the first 5 days, but covered later), (4) = 50 % open late (caged at the first half of the blooming period and open pollination afterwards) (5) = 35 % open late (caged during the first two third of the blooming period and open pollination afterwards by the last third of flowering) (6) = 100 % open (free pollination, no caging). Not all the variables were applied at each experiment. Fruit set was measured three times at the branches but only the final set was evaluated in this study (*Tables* 8–9).

The effect of bee pollination on the fruit size of sour cherry

At harvest time all fruits were harvested from the experimental branches and each was weighted individually in some of the previous type of experiments. So the mean mass of individual fruits was counted and this value was related to the final fruit set (*Table* 9). Four cultivars were included in this research, three of them (*Újfehértói fürtös, Kántorjánosi, Debreceni bőtermő*) were self fertile and the fourth one was a self sterile variety (*Pándy 279*).

Results ad discussion

Flower size and the relative position of flower organs

No similar data were published in the literature except our studies (*Benedek*, et al., 1990). The diameter of flowers, the number of stamens per flower, the relative position of stamens to petals and the relative position of pistil to stamens are shown in *Table* 1.

As clearly shown their relatively small flowers distinguish the Cigánymeggy-types of cultivars, whereas the flowers of *Pándy* and of other tart cherry cultivars are conspicuously larger, almost as large as the sweet cherry flowers (*Benedek* & *Nyéki* 1994). Small flowers are usually less conspicuous to bees approaching the flowers but in the case of sweet cherry the observed differences were so small that may not have any impact to bee behaviour.

The number of stamina was round 30, changing a bit in consecutive years. The mean number of stamen per flower was a bit more at some cultivars in the first year and was more in the second but the reverse was true for other cultivars. The differences were not significant at most cases (*Table* 1). Additionally, the minor differences were not consequent according to the season.

The position of stamina is distinct from the sweet cherry (*Benedek* & *Nyéki* 1994), i.e. rather sprawling instead of being stiff or medium erect (*Benedek* et al.,1990). That is important to prevent the behaviour of "side worker" nectar

Table 1 Some morphological features of flowers of selected sour cherry cultivars (Helvécia 1988–1989)

Cultivar	Year	Flower size (diameter in mm)	No. of stamens per flower	Relative position of stamens to petals (ratio of different types* in per cent)				Re'ative position of pistil to the stamens (ratio of different types** in per cent)				
				1	2	3	4	1	2	3	4	5
Cigány meggy 7	1988 1989	23.00 24.67	29.30 32.57	0 0	16.67 0	83.33 100	0 0	0 0	76.67 0	23.33 100	0 0	0 0
Cigány meggy 59	1988 1989	24.20 23.60	30.13 28.43	0 0	10.00 23.33	90.00 76.67	0 0	0 0	0 6.67	90.00 93.33	10.00 0	0 0
Cigány meggy 404	1989	24.67	31.63	0	10.00	86.67	3.33	0	0	100	0	0
Debreceni bőtermő	1989	32.07	29.87	0	0	20.00	80.00	0	0	20.60	80.00	0
Fanal	1989	–	29.37	0	10.00	90.00	0	0	0	100	0	0
Hartai meggy	1989	24.20	30.73	3.33	70.00	26.67	0	0	3.33	33.33	63.33	0
Kántorjánosi 1	1988 1989	33.20 35.63	30.70 30.10	0 0	0 0	100 100	0 0	0 0	36.67 0	63.33 100	0 0	0 0
Kecel 1	1989	–	28.70	0	0	100	0	0	10.00	90.00	0	0
Parasztmerggy	1989	23.13	28.70	0	20.00	63.33	16.67	0	0	46.67	53.33	0
Pándy meggy 7	1988 1989	36.17 33.00	31.53 30.33	0 0	0 0	100 40.00	0 60.00	0 0	0 0	96.67 40.00	3.33 60.00	0 0
Újfehértói fürtös	1988 1989	32.93 31.90	30.50 31.60	0 0	3.33 6.67	96.67 43.33	0 50.00	0 0	6.67 0	76.67 36.67	16.66 63.33	0 0
Mean	1988 1989	29.90 28.10	30.43 30.18	0 0.41	6.00 13.30	94.00 67.16	0 19.10	0 0	24.00 1.82	70.00 69.09	6.00 29.09	0 0
SD5 %	1988 1989	1.2 1.2	1.0 1.2	– –	– –	– –	– –	– –	– –	– –	– –	– –

* the stamens are 1=rigidly stiff (standing close to vertical), 2=of medium position, 3=sprawling (close to petals), 4=of mixed position

** the pistil is 1=absent, 2=small (below the level of petals), 3=medium (below the level of anthers), 4=high (at the same level as anthers), 5=very high (above the level of anthers)

Table 2 Nectar production of flowers of selected sour cherry cultivars (Helvécia, 1988–1989)

Year:	1988				1989			
Cultivar	**Time of sampling**	**Nectar content of flowers (mg/flower)**	**Sugar concentration (per cent)**	**Sugar content (mg/flower)**	**Time of sampling**	**Nectar content of flowers (mg/flower)**	**Sugar concentration (per cent)**	**Sugar content (mg/flower)**
Cigány meggy 7	22.04. p.m.	1.32	60.00	0.79	09.04. p.m..	2.13	34.2	0.73
	26.04. a.m..	0.61	28.80	0.18				
	27.04. a.m..	2.72	40.30	1.10				
	28.04. a.m..	2.84	52.60	1.49				
	Mean	**1.87**	**45.40**	**0.89**				
Cigány meggy 59	22.04. p.m..	0.64	52.80	0.34	09.04. a.m..	3.62	42.20	1.53
	26.04. a.m..	0.79	35.80	0.28	09.04. p.m..	1.07	40.80	0.44
	27.04. a.m..	2.33	46.60	1.08				
	28.04. a.m..	3.82	52.60	2.01				
	Mean	**1.90**	**46.90**	**0.93**		**2.34**	**41.80**	**0.98**
Cigány meggy 404	27.04. a.m..	2.16	56.90	1.23	09.04. a.m..	0.54	60.60	0.33
	28.04. a.m..	4.34	50.40	2.19	09.04. p.m..	0.70	44.20	0.31
	Mean	**2.17**	**53.70**	**1.40**	**Mean**	**0.62**	**52.40**	**0.32**
Kántorjánosi 1	22.04 p.m..	5.26	30.20	1.59	09.04. a.m..	1.60	62.90	1.01
	26.04. a.m..	5.13	22.00	1.13	09.04. p.m..	5.35	41.40	2.21
	27.04. a.m..	7.50	29.60	2.22				
	28.04. a.m..	18.00	32.10	5.79				
	Mean	**8.97**	**28.50**	**2.68**	**Mean**	**3.47**	**52.10**	**1.61**
Pándy meggy 7	22.04. p.m..	6.14	43.70	2.68	09.04 a.m..	4.35	41.10	1.79
	27.04. a.m..	8.90	42.70	3.80	09.04. p.m..	11.38	18.00	2.05
	28.04. a.m..	18.63	20.90	3.89				
	Mean	**8.26**	**35.80**	**3.46**	**Mean**	**7.86**	**29.60**	**1.92**
Újfehértúi fürtös	22.04. p.m..	6.74	52.00	3.50	09.04. a.m..	1.94	58.60	1.14
	26.04. a.m..	1.42	18.70	0.26	09.04. p.m..	4.38	48.30	2.12
	27.04. a.m..	11.60	24.00	2.78				
	28.04. a.m..	14.70	31.90	4.69				
	Mean	**8.61**	**31.60**	**2.06**	**Mean**	**3.16**	**53.40**	**1.63**
Fanal	–	–	–	–	04.09. a.m..	0.72	39.90	0.29
					04.09. p.m..	1.85	37.50	0.69
					Mean	**1.28**	**38.**	**0.49**
Hartai meggy	–	–	–	–	04.09. a.m..	0.43	58.10	0.25
					04.09. a.m..	2.10	55.90	1.17
Kecel 1	–	–	–	–	04.09. p.m..	2.32	53.50	1.24
					Mean	**2.21**	**54.70**	**1.20**
Parasztmeggy	–	–	–	–	04.09. a.m..	1.15	51.30	0.59
					04.09. a.m..	4.14	48.10	1.99
Debreceni bőtermő	–	–	–	–	04.09. p.m..	2.86	57.20	1.64
					Mean	**3.50**	**52.60**	**1.81**
Grand mean	–	*5.44*	*39.26*	*1.91*		*2.76*	*2.60*	*1.02*

gatherers that avoid the contact with the stigma and, consequently, do not pollinate it. However, the position of stamina to the petals was rather variable according to the season and the cultivar (*Table* 1). Most stamina were sprawling in both years of observations but the proportion of rigid stamina was much greater in the first than in the second year. No definitely stiff stamina occurred in the first but appeared in a very small ratio in the second year. Mixed position stamina were absent but appeared in a measurable quantity in the second year. The ratio of stamina with different positions was sometimes rather different according to the year in the case of some cultivars inspected. Great differences were established both in the case of *Cigánymeggy*, tart cherry *(Pándy)* and sweet-sour cherry cultivars (*Kántorjánosi, Újfehértói fürtös*).

The stigma was positioned more or less below the anthers and sometimes it was positioned at the same level but it was not positioned above the anthers in any case (*Table* 1). The position of stamina proved to be hardly distinguished clearly according to the cultivars but is definitely influenced by the season (*Table* 1). The relative position of the pistil to the stamens was highly variable but not so much due to the cultivars but rather as a seasonal effect (*Table* 1).

Nectar production of flowers

Results on the nectar production (nectar content) of sour cherry flowers are summarized in *Table* 2. The nectar production (nectar content) of flowers was rather variable; the extremes were 0.61 and 18.63 mg per flower per day. Also the sugar concentration in nectar ranged between greatly different values the extremes were varied 18.00 and 62.9 per cent, respectively. The mean nectar production of flowers was 5.44 and 2.76 and the sugar concentration in nectars was 40–43 % in the two consecutive years of the study (*Table* 2). This means sour cherry nectars contained 1.91 and 1.02 mg sugar per flower in average in the years in question (*Benedek* et al., 1990). *Paarmann* (1980) measured 4.7–7.4 mg per flower, only. *Péter* (1972) gave a survey on contradictory data. The deviations may be understood on base of the results of *Péter* (1972) because the amount of nectar changes according to weather conditions and also with the progress of blooming, moreover daytime (*Orosz-Kovács,* 1992; *Orosz-Kovács* et al. 1989, 2000). *Péter* (1972) proved that rainy weather increased the quantity of nectar and lowered the sugar content. Nectar production of sour cherry seems to be exceptional among the fruit species because in spite of the high productivity the sugar content used to be relatively high (*Benedek & Nyéki* 1997). Nevertheless, quantity and sugar content are inversely associated in cultivars within the species. The cultivar *Pándy* and similar high quality tart cherries, which are self-fertile too, are more productive than others with small, less attractive fruit as "*Cigánymeggy*" cultivars (*Parnia* et al., 1979, *Benedek* et al., 1996).

As far as individual cultivars are concerned the nectar production and the sugar concentration in nectars were rather variable according to the time of sampling (*Table* 2). The nectar production (nectar content) was two to six times more very often at a specific sapling date than at other one at the same cultivar (*Table* 2). In nectar production, differences are revealed rather between groups of cultivars than between individual cultivars. This statement clearly contradicts to *Simidchiev* (1971) who claimed that different degrees of nectar production were associated with cultivars, which has not been confirmed by our observations. However, the mean amount of nectar in sour cherry flowers and the sugar content in nectar are fairly similar in *Simidchiev's* (1971) than in our study.

Orosz-Kovács et al. (1989, 1992) stated that sour cherry flowers produced nectar over several days, whereas the maximum was found about in the middle of the lifetime of the flowers, i.e. approximately on the third day of their opening. It was stated that sour cherry flowers secreted nectar, rhythmically, at 6-hour intervals. Later it turned out that the time of maximal nectar secretion and rate of the fertilisation of the flowers were positively correlated (*Orosz-Kovács*, 1990).

Pollen production of flowers

Result on the pollen production of sour cherry flowers are shown in *Table* 3. The mean number of pollen grains per anther in sour cherry flowers was 3500 to 1 550 and the number of grains per flower was from 9 810 to 42 980 per flower (prior to the dehiscence of anthers). The pollen production of flowers, however, was extremely changeable in consecutive years (*Table* 3). In the case of *Cigánymeggy 7* for example it was as much as 21 975 in one and not more than 9 810 in the next year. In the case of the cultivar *Újfehértói fürtös* the pollen production of flowers differed even at a greater extent in two consecutive years because the pollen production of the flowers was three times more in one than in the other year (*Table* 3). The mean number of pollen grains per anther in sour cherry flowers is, therefore, greatly variable seasonally and cannot be regarded to the cultivar similarly as in sweet cherry (*Benedek & Nyéki* 1994).We found that in spite of the abundant nectar production of sour cherry flowers (*Benedek* et al., 1990), the attractiveness of the abundant nectar seems to be surpassed by profuse pollen supply, which is comparable with that of sweet cherry (*Benedek* et al., 1996, *Benedek & Nyéki* 1994).

Table 3 Pollen production of flowers of selected sour cherry cultivars (Helvécia, 1988–1989)

Cultivar	Year	No. of pollen grains per anther	Calculated pollen production of flowers (No. of pollen grains per flower)
Cigány meggy 7	1988	750	21 975
	1989	300	9810
Cigány meggy 59	1988	850	25 610
Kántorjánosi 1	1988	1400	42 980
Pándy meggy 7	1988	600	18 900
	1989	550	16 680
Újfehértói fürtös	1988	1550	35 075
	1989	350	11 060
Mean		*793*	*22 761*

Honeybee visitation of and the gathering behaviour of honeybees at sour cherry flowers

The average number of bee visits per 100 flowers per 10 minutes was a bit more at *Cigány meggy* and somewhat less at *Pándy meggy* but the difference was not really significant (*Tables* 4–5). Weather (first of all wind at the periods of observations) had a stronger effect on the changing pattern of bee visitation in general than some probable effect of cultivars. Most honeybees collected nectar at sour cherry flowers; their ratio was 46–51 per cent at both sites (*Tables* 4–5). Pure pollen gatherers were as frequent as 22–35 per cent and mixed behaviour bees as 21–25 per cent. Mixed behaviour bees are almost as effective pollinating agents as pure pollen gatherers and so they should be counted together with that. We can state, therefore that some 47 to 56 per cent of flower visiting bee collected pollen at sour cherry flowers in one or another way. Side workers among the nectar gatherers were not detected at sour cherry at all. No pollen gatherers were found and three cultivars and no mixed

Table 4 Comparison of gathering behaviour of honeybees at sour cherry cultivars at Helvécia, on the 29th of April 1988

Cultivar	Observation period	No. of inspected flowers	No. of honeybee forages at 100 open flowers in 10 minutes periods				Air Tempe-rature (°C)	Cloud cover (per cent)	Wind speed after the Baufort scale (B°) (13)
			Pollen gatherers	Nectar gatherers: approaching from the top of the flowers (7)	Nectar gatherers: side workers	Mixed behaviour bees (gathering both pollen and nectar)			
Pándy meggy 7	11:10-11:20	122	0.8	0.8	0	0	20	60	3
Újfehértói fürtös	11:21-11:31	196	1.02	0.5	0	0.5	21	60	3
Cigány meggy 404	11:32-11:42	107	0.9	0.9	0	0.9	21	60	3
Cigány meggy 59	11:43-11:53	96	2.08	1.04	0	1.04	21	60	3
Cigány meggy 7	12:07-12:04	95	1.05	1.05	0	0	20	70	3
Hartai meggy	12:07-12:17	189	1.06	0.5	0	1.06	20	70	3
Kecel 1	12:20-12:30	107	0.9	1.9	0	0.9	20	60	3
Fanal	12:35-12:45	107	1.9	0	0	1.9	20	60	4
Parasztmeggy	12:46-12:56	91	0	2.2	0	0	20	60	4
Kántorjánosi 1	1:00-1:10	90	0	1.1	0	1.1	20	60	4
Debreceni bőtermő	1:15-1:25	165	0	1.2	0	0	20	60	4
Érdi bőtermő	12:30-12:40	140	2.1	3.6	0	0	20	0	2
Mean	–	***125,4***	***0.98***	***1.23***	***0***	***0.62***	–	–	–
Per cent ratio of bees with different gathering behaviour			***34.6***	***43.6***	***0***	***21.8***	–	–	–

Table 5 Comparison of honeybee visitation at sour cherry cultivars at Kecskemét, on the 29th of April 1988

Cultivar	Observation period	Part of the crown	No. of inspected flowers	Distance from the beehives (m)	No. of honeybee forages at 100 open flowers in 10 minutes periods				Air tempera ture (°C)	Cloud cover (per cent)	Wind speed after the Baufort scale (B°) (13)
					Pollen gatherers	Nectar gatherer approach ing from the top of the flowers	Nectar gatherer side workers	Mixed behaviour bees (gathering pollen and nectar)			
Pándy 7 meggy	10:52-11:02	South East	88 65	50	4.0 0	0 0	0 0	0 0	18	0	1
	11:11-11:21	South East	126 10	100	0.8 0	0.8 0	0 0	0 0	18.	0	1
	11:27-11:37	South East	100 89	200	2.0 0	1.0 0	0 0	1.0 0	18	0	1
	11:46-11:56	South East	85 78	400	2.4 0	0 0	0 0	0 0	18	5	1
	12:07-12:17	South East	85 78	400	0 1.3	0 0	0 0	0 0	20	5	2
	12:22-12:32	South East	105 115	200	0 0	0.9 0	0 0	0.9 0	20	30	2
	12:36-12:46	South East	87 92	100	0 0	1.1 0	0 0	1.1 1.1	20	30	2
	12:50-13:00	South East	112 56	50	0.9 0	3.6 0	0 0	0.9 4.4	20	30	2
	13:28-13:38	South East	88 65	50	1.1 0	3.4 10.5	0 0	1.1 0	20	40	1
	13:51-14:01	South East	84 87	100	0 0	0 2.3	0 0	0 1.1	20	40	1
	14:04-14:14	South East	100 89	200	0 0	1.0 0	0 0	0 1.1	20	40	4
	14:19-14:29	South East	85 82	400	0 1.2	0 0	0 0	0 0	20	40	3

Table 5 Comparison of honeybee visitation at sour cherry cultivars at Kecskemét, on the 29th of April 1988 continu

Cultivar	Observation period	Part of the crown	No. of inspected flowers	Distance from the beehives (m)	No. of honeybee forages at 100 open flowers in 10 minutes periods				Air tempera ture (°C)	Cloud cover (per cent)	Wind speed after the Baufort scale (B°) (13)
					Pollen gatherers	Nectar gatherer approach ing from the top of the flowers	Nectar gatherer side workers	Mixed behaviour bees (gathering pollen and nectar)			
	14:33-14:43	South East	71 104	400	0 0	0 0	0 0	0 0	20	40	3
	14:45-14:55	South East	100 89	200	0 0	1.0 1.1	0 0	0 0	20	40	2
	14:57-14:07	South East	84 87	100	0 0	1.2 0	a0 0	0 1.1	20	30	2
	15:08-15:18	South East	112 56	50	0 0	0.9 1.8	0 0	0 0	20	30	2
	Mean	–	–	–	***0.4***	***1.0***	***0***	***0.5***	–	–	–
Per cent ratio of bees with different gathering behaviour					***22.1***	***52.5***	***0***	***25.4***	–	–	–
Cigány 7 meggy	10:52-11:02	South East	69 77	50	11.6 3.9	0 0	0 0	0 0	18	0	1
	11:11-11:21	South East	68 135	100	1.4 3.7	0 0	0 0	0 0	18 18	0	1
	11:27-11:37	South East	52 106	200	1.9 1.9	3.8 4.7	0 0	0 0	18	0	1
	11:46-11:56	South East	101 97	400	1.0 2.1	2.9 0	0 0	4.0 1.03	18	5	1
	12:07-12:17	South East	80 84	400	1.3 1.2	1.3 1.2	0 0	2.6 1.2	20	5	2
	12:22-12:32	South East	82 69	200	1.2 2.9	0 1.4	0 0	0 4.3	20	30	2
	12:36-12:46	South East	40 56	100	0 5.3	0 0	0 0	5.4 1.8	20	30	2
	12:50-13:00	South East	63 89	50	1.6 2.2	1.6 0	0 0	0 2.2	20	30	2
	13:28-13:38	South East	50 89	50 0	0 1.1	2.0 3.4	0 0	4.0 2.2	20	40	1
	13:51-14:01	South East	100 100	100	1.0 2.1	1.0 1.0	0 0	0 2.0	20	40	1
	14:04-14:14	South East	105 109	200	0 0	0 0	0 0.9	0 0.9	20	40	4
	14:19-14:29	South East	88 102	400	1.1 0	2.3 1.0	0 0	1.1 3.9	20	40	3
	14:33-14:43	South East	85 56	400	1.2 0	1.2 0	0 0	0 0	20	40	3
	14:45-14:55	South East	85 87	200	0 0	1.2 0	0 0	1.2 0	20	40	2
	14:57-15:07	South East	104 100	100	1.9 0.4	1.9 2.0	0 0	1.0 1.0	20	30	2
	15:08-15:18	South East	87 40	50	0 0	0 7.5	0 0	0 0	20	30	2
	Mean	–	–	–	***1.3***	***2.6***	***0***	***1.2***	–	–	–
Per cent ratio of bees with different gathering behaviour					***25.2***	***50.5***	***0***	***24.3***	–	–	–

behaviour bees at other three ones (*Table* 4), these figures, however, were rather the consequences of the short (10 minutes') observation periods than of any differences among cultivars. This can be corroborated by the fact that at one other place where a number of 10 minutes' observations were made at two selected cultivars the appearance of behaviour classes was rather different in concluding observations (*Table* 5). Accordingly, differences among the behaviour of honeybees according to cultivars cannot be stated (*Benedek* et al., 1990).

Table 6 Fidelity of pollen gatherer honeybees to sour cherry as pollen source (Pomáz, 1993–1994)

Parameter		**Sampling data**	
		24.04.1993	**16.04.1994**
Number of pollen loads analysed		85	167
Distribution of pollen loads after the amount (per cent) of contaminating pollen species	0 % contamination(pure sour cherry)	37.6	49.1
	>2 % contamination	5.9	4.2
	2–10 % contamination	36.5	30.5
	10.1–20 % contamination	17.7	15.6
	20.1–30 % contamination	2.3	0.6
	30.1–100 % contamination	0	0
Contaminating pollen species		55.8 % Lamium purpureum 27.6 % Capsella bursa-pastoris 1.0 % Geraniaceae 15.6 % Unidentified	41.3 % Taraxacum officinale 26.7 % Lamium purpureum 12.9 % Capsella bursa-pastoris 0.4 % Geraniaceae 18.7 % Unidentified

Fidelity of honeybees to flowering sour cherry trees

The fidelity of honeybees to sour cherry is less expressed than to apple, apricot or pear (*Benedek & Nagy*, 1995), because a high ratio (47–57 %) of pollen loads of honeybees visiting sour cherries was mixed with pollen grains of other species (*Table* 6). The mixed („contaminated") loads contained more foreign pollen than experienced in other fruit species (*Benedek & Nagy*, 1995). The proportion of pure loads was round 40–50 per cent and added with the loads with minor (>2 %) contamination, that can be regarded as accidental mistakes by flower visiting bees with no deliberate action at other flowers, the ratio of quasi pure loads was 44–53 per cent. However, the ratio of loads with small amount (2–10 %) of contamination was very high (30–36 %) and this means that some plant species flowering simultaneously strongly influence pollen gathering honeybees on sour cherry flowers. Accordingly, in organizing additional bee pollination the competition of other plant species (weeds) flowering in and around sour cherry orchard should be carefully taken into account. The sources of contamination were species mainly as *Lamium purpureum*, *Taraxacum officinale* or *Capsella bursa-pastoris* and some *Geraniaceae* (*Table* 6). All these plants are common weeds in flowering sour cherry orchards, therefore, it is very strongly suggested to mow the grass with weeds prior to the flowering period in sour cherry orchards were additional bee pollination is planned to be applied to get a good yield.

Fruit set of sour cherry cultivars at caged flowers (no bee activity: self fertilization) as compared to free pollination

Self fertilization capacity of cultivars was compared to free pollination at four localities in three years (*Table 7*). Fruit set at caged branches (self fertilization) was greatly variable according to the cultivars and the years, the extremes being 0 to 40.13 per cent (*Table* 7). There were two cultivars, *Pándy meggy* and *Kecel I* that did not produce any fruit when caged. These are known to be as definitely self incompatible cultivars (*Nyéki & Soltész*, 1996). All other cultivars inspected produced some amount of fruit when caged all along the flowering period except in one experiment when no set was registered in the covered flowers (Újfehértó, 1998); but in this case all fruit set figures were much lower – for bad weather during the flowering period – than in the rest of the experimentation (*Table* 7). Cultivar *Fanal* was of the greatest self-fertilization capacity followed by the *Cigánymeggy* types and by *Parasztmeggy* (*Table* 7). *Fanal* showed extremely high self-fertilization capacity and, surprisingly, it produced less fruit when exposed to free (bee) pollination (uncovered). So its reaction was clearly the opposite to free (bee) pollination than the same of the other cultivars tested (*Table* 7). The rest of the cultivars produced much less fruit when caged but their fruiting capacity was round 5–15 per cent (or more) except the unfavourable case mentioned above (Újfehértó, 1998). However, their self fertilization capacity was resulted in much smaller fruit set even in favourable cases (not counting Újfehértó, 1998), fruit set being at least twice to 5 or 9 times more at uncovered branches with free pollination than on branched caged excluding bee activity (*Table* 7). Fruit set both on uncovered branches and on branches caged during the flowering period was rather different in the experiments at different sites and years (*Table* 7). This means that self-fertilization capacity and, of course, the effect of open (bee) pollination is greatly dependent on the conditions of the site and the year. With the exception of a single cultivar, *Fanal*, all inspected cultivars clearly require open (bee) pollination to produce satisfactory yields. This statement refers to the inspected new, sour-sweet cherry type cultivars (*Debreceni bőtermő, Kántorjánosi, Újfehértói fürtös*) too, that are regarded to be "self-fruitiful" ones in the practice. It is also plausible that the strictly self-ufruitiful cultivars examined (*Pándy, Kecel*) produce much less fruit at open (bee) pollination than the cultivars of more or less self-fertilization capacity (*Table* 7).

Table 7 Comparison of fruit set of sour cherry cultivars when caged in flower (self fertilization) and under free (bee) pollination

Cultivar	Site and year							
	Kecskemét, 1988 (fruit set, per cent)		Helvécia, 1988 (fruit set, per cent)		Helvécia, 1989 (fruit set, per cent)		Ujfehértó, 1998 (fruit set, per cent)	
	self fertili-zation (caged)	free pollination (uncovered)	*self fertili-zation (caged)*	free pollination (uncovered)	*self fertili-zation (caged)*	free pollination (uncovered)	*self fertili-zation (caged)*	free pollination (uncovered)
Cigánymeggy 7	*11.1*	32.1	*6.81*	21.39	*17.41*	37.41	–	–
Cigánymeggy 59	–	–	*8.62*	31.02	*11.65*	36.64	–	–
Cigánymeggy C 404	–	–	*4.43*	24.45	*8.22*	33.07	–	–
Debreceni bőtermő	–	–	*1.43*	9.39	*6.79*	31.82	*0*	5.5
Fanal	–	–	*40.13*	20.36	*23.05*	16.45	–	–
Hartai	–	–		–	*6.91*	39.70	–	–
Kántorjánosi 1	–	–	*5.20*	17.44	*6.73*	37.14	*-0*	5.7
Kecel 1	–	–		–	*0*	9.42	–	–
Paraszt meggy	–	–	*14.65*	33.62	*17.13*	42.66	–	–
Pándy meggy 7	*0*	4.8	*0*	7.02	*0*	27.00	*0*	6.4
Újfehértói fürtös	*10.0*	31.4	*3.22*	15.69	*12.16*	35.71	*0*	4.6

Limiting the effective bee pollination period

Self-incompatible sour cherry cultivars, as for their yield, are considered to be relied obligatorily on pollinating insects (*Free*, 1993; *Benedek*, 1996). The question of the requirement of self-fertile cultivars has been open for a long time. Accordingly, we made experiment to clear up this problem.

The weather was favourable to bee activity and to pollination all along the flowering period of sour cherry at our Kecskemét experiment in1988. The self-sterile *Pándy meggy* cultivar reacted very sharply both on the partial and total restriction of bee pollination (*Table* 8). Fruit set dropped to one third when branches were caged from the 6th day and was reduced to one fifth when they were covered a bit earlier, that is from the 4th day of blooming, and complete restriction resulted in no yield. Partly self-fruitiful cultivars (*Cigánymeggy 7, Újfehértói fürtös*) also reacted on the limitation of bee pollination but their reaction was no so sharp. Minor limitation (caging from the 6th day) did not produced any effect but the caging somewhat earlier (covering from the 4th day) resulted in a significantly smaller set for one cultivar (*Cigánymeggy*) but the same level of set for the other variety (*Újfehértói fürtös*). Both partly self-fruitiful varieties produced significantly lees – some one third – fruit set only when bee pollination was totally limited compared to free pollination when bees frequented flowers free (*Table* 8).

At the other experiment in 1998 the weather was rather bad to bee activity and to fruit set in general during the flowering period of sour cherry except the last third of the flowering. For this reason the set values were quite modest (*Table* 9), highest figures being less than half to one third of the earlier ones obtained in 1998 (see in *Table* 8). In the case of total caging interestingly no yield was obtained even at the cultivars being partly self-fruitiful and so producing some amount of fruit in normal (favourable) weather even in a total exclusion of bees (see in *Table* 8). Greatest fruit set figures were obtained at free pollination and in the case when flowering branches were open at the second part (second half or last third) of the flowering period because the weather was not so much unfavourable this time than in the first part of the blooming (*Table* 9). Restricted bee pollination affected the partly self-fruitiful *Debreceni bőtermő* and the self-sterile *Pándy* much more than the other two partly self-fruitiful cultivars. In fact all cultivars reacted on the restriction of bee pollination period definitely. And also the effect of bad

Table 8 The effect of limited bee pollination on the fruit set of some sour cherry cultivars (Kecskemét, 1988)

Cultivar	Fruit set (per cent)					
	Year	0 % open = covered during the flowering period to exclude pollination by bees	35 % open first = caged from the 4th day of the flowering	67 % open first = caged after the 5th day of flowering	100 % open = free pollination (uncovered)	Significant Difference (p<0.05)
Pándy meggy 7 (self sterile)	1988	0	1.0	1.5	4.8	0.6
Cigány meggy 7 (partly self-fruitiful)	**1988**	11,1	26.7	31.0	32.1	3.7
Újfehértói fürtös (partly self-fruitiful)	1989	10,0	32.3	32.1	31.4	5.8

Table 9 Final set and the mean mass of individual fruits at sour cherry trees (Ujfehértó, 1998)

Cultivar	Treatment	Final fruit set (per cent) (n=4)	Mean mass of individual fruits (g)
Újfehértói fürtös (partly self-fruitiful)	0 % open (caged)	0	–
	50 % open early (in the first half of flowering)	0.5 ± 0.5	5.9 (n=1)
	50 % open late (in the second half of flowering)	9.4 ±0.8	5.3 ± 0.2 (n=30)
	35 % open late (in the last third of flowering)	10.1 ± 3.9	5.0 ± 0.2 (n=21)
	100 % open	10.8 ± 5.3	4.6 ± 0.1 (n=35)
Kántorjánosi 1 (partly self-fruitiful)	0 % open (caged)	0	–
	50 % open early (in the first half of flowering)	0.1 ± 0.1	4.9 (n=1)
	50 % open late (in the second half of flowering)	9.6 ± 1.8	5.5 ± 0.1 (n=27)
	35 % open late (in the last third of flowering)	14.0 ± 8.6	5.0 ± 0.1 (n=31)
	100 % open	9.5 ± 1.4	5.7 ± 0.4 (n=12)
Debreceni bőtermő (partly self-fruitiful)	0 % open (caged)	0	–
	50 % open early (in the first half of flowering)	0	–
	50 % open late (in the second half of flowering)	4.0 ± 2.7	6.4 ± 0.2 (n=7)
	35 % open late (in the last third of flowering)	3.1 ± 3.1	destroyed
	100 % open	8.8 ± 4.4	5.5 ± 0.1 (n=22)
Pándy meggy 279 (self sterile)	0 % open (caged)	0	–
	50 % open early (in the first half of flowering)	0.3 ± 0.3	6.4 (n=1)
	50 % open late (in the second half of flowering)	0.6 ± 0.3	7.0 ± 1.3 (n=2)
	35 % open late (in the last third of flowering)	2.4 ± 0.7	6.9 ± 0.2 (n=7)
	100 % open	2.7 ± 1.0	6.4 ± 0.3 (n=8)

weather was observed to be very similar to the effect of the exclusion of bees.

It is clearly shown that in the experiments yield was reduced not only by the total exclusion of insects but also in consequence of partial restriction of the effective bee pollination period. We can conclude that the total lack of pollinating agents is deleterious not only to the self-incompatible *Pándy* cultivar but decisively revealed in the yield of partly self-fruitiful cultivars as *Cigánymeggy, Kántorjánosi, Debreceni bőtermő* and *Újfehértói fürtös*. The partial restriction of pollination is also decisively stated in the self-incompatible *Pándy*. At partly self-fruitiful cultivars, on the other hand, in favourable weather the partial limitation of the bee pollination period hardly reduced the fruit set as compared to the free pollination (uncaged).

It is clearly evident from the above results that self-sterile sour cherry cultivars are sensitive even on the partial restriction of the effective time of bee pollination and it is to be stressed too that even in the case of partly self-fruitiful cultivars bee pollination can also be vital in yield formation of sour cherries as *Benedek* et al. (1990), *Benedek* et al. (2005) as well as *Benedek* et al. (2001) stated.

The effect of bee pollination on the fruit size of sour cherry

As sour cherry is fairly attractive to honeybees intense bee visitation can result in high fruit set. Heavy set, however, is usually believed to cause smaller fruit size. *Griggs* (1970), therefore, expressed the opinion, that heavy set at self-fertile sweet cherry cultivars may be undesirable for the reduced fruit size. This statement, however, is based on practical experiences only but no experimental verification was available and the critical level of fruit set at which the mass of fruits decreases greatly was unknown too. Accordingly, we made an experiment (*Table* 9) to study the effect of fruit set on the mean mass of fruits at four sour cherry cultivars (one was self-sterile and the other three partly self-fruitiful).The cultivars tested are characterised by somewhat different mean fruit sizes (*Nyéki* et al., 2000). First of all, the tested self sterile variety (*Pándy 279*) is regarded to have greater mean fruit mass that the others (6.3 g in average). This variety, however, is known to get always much smaller fruit set than the other tested cultivars. The fruit set of that was even much lower than general in our experiment (1.5 per cent in average only) and its mean fruit mass was somewhat greater (6.7 g) than the typical average (6.3 g). The characteristic fruit sizes of the other tested cultivars are not so great and these are much more close to each other (being 5.6 g of *Kántorjánosi*, 5.5 g of *Újfehértói fürtös* and 5.3 g of *Debreceni bőtermő*). In spite of these facts, all the available data pairs were analysed collectively to explore the relationship between the final fruit set and the fruit sizes (their mean mass). We found that the mass of individual fruits seemed to be more or less proportional with the final set at all cultivars tested because smaller sets were connected to greater, while greater sets to at least somewhat smaller fruit sizes at most instances (*Table* 9). As a result, a fairly reasonable and significant negative correlation was detected between the final set and the mean mass (the size) of the fruits ($r = -0{,}66$, $n = 14$, $p<0.01$) as *Benedek* et al. (2001) stated.

The relationship was also attempted to analyse excluding the data for *Pándy meggy 279* that was characterised by much greater fruit size than the other varieties. In this case the relationship was also negative but it was much less expressed and it was not statistically significant ($r = -0.4$, $n = 10$, not significant at the $p = 10$ % level). Accordingly, the significant negative correlation with *Pándy* is rather a function of the small setting capacity of this variety and of its genetically greater mean fruit size than of a valid relationship between the set and the fruit size in general.

Conclusions

1 Flower characters of sour cherry are fairly similar to other temperate zone fruit tree species. Their relatively small flowers distinguish the Cigánymeggy-types of cultivars from the flowers of tart cherries cultivars that are conspicuously larger, almost as large as the sweet cherry flowers. The relative position of flower organs, however, are much more variable according to the season than according to the cultivars.

2 Sour cherry flowers produce more abundant nectar than most other temperate zone fruit tree species but the attractiveness of the abundant nectar seems to be surpassed by profuse pollen supply that is comparable with that of sweet cherry. However, the pollen production of flowers is extremely changeable in consecutive years.

3. Most honeybees gather nectar at sour cherry flowers; pure pollen gatherers and mixed behaviour bees are half as frequent but differences among the behaviour of honeybees according to cultivars cannot be stated.

4. The fidelity of honeybees to sour cherry is less expressed than to some other fruit tree species. Accordingly, it is very strongly suggested to take the competitive effect other plant species (weeds) flowering in and around the orchard carefully into account when organizing additional bee pollination in sour cherry plantations.

5. Several sour cherry cultivars possess more or less self-fertilization capacity but this is greatly changeable according to the season.

6. It has been proved that self-sterile sour cherry cultivars are sensitive even on the partial restriction of the effective time of bee pollination and it is to be stressed too that even in the case of partly self-fruitiful cultivars bee pollination is also vital in yield formation because medium or strong restriction of the effective bee pollination period is of a definite negative effect on their fruit set and yield. In years with unfavourable weather, the yield can dramatically be reduced.

7. Very high fruit set may also be unfavourable because significant negative correlation was detected between the final set and the mean mass of fruits.

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